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(54) **A flow recovery system for hydraulic circuits with pumps and pressure compensated distributor valves for working members of earth-moving machines.**

(57) A hydraulic control circuit for the working members of earth-moving machines having linear and rotary reversible hydraulic actuators (1-7) each of which is associated with an associated hydraulic distributor valve (8, 9) and a pressure compensator (17, 18) of the "load-sensing" type. One or more of the actuators (1-7) is further associated with a flow recovery device (25) including at least one recovery line (34) between the discharge (28) and the delivery (27) of the actuator for obtaining an additional closure pressure on the spool (29) of the compensator (17, 18) in such a way as to cancel out unnecessary demands on the fluid flow rate from the pump (12).

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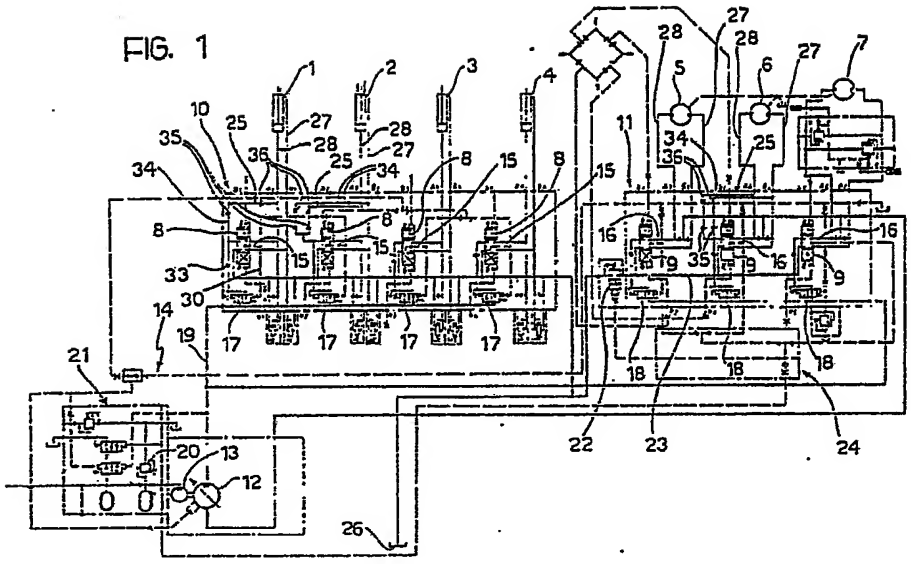
FIG. 1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A flow recovery system for hydraulic circuits with pumps and pressure-compensated distributor valves for working members of earth-moving machines

The present invention relates in general to hydraulic control circuits for the working members of earth-moving machines.

More particularly, the invention relates to a hydraulic control circuit of the type including a pump for supplying a hydraulic fluid under pressure and a plurality of reversible hydraulic actuators, in part linear and in part rotary, for the actuation of respective working members each of which has an associated hydraulic spool valve connected with the delivery and the discharge of the associated working member and positionable, with continuous adjustment, by means of associated control means, into three positions corresponding to displacement of the working member in a first direction, stopping thereof, and displacement in a second direction opposite the first, and pressure compensators of the "load-sensing" type interposed between the said source of supply and the said distributor valves for maintaining the difference between the pressure delivered by the said supply source and the pressure in the working members substantially constant, the said pressure compensators including normally open two-way spool valves each having an end subjected to an opening pressure coming from the associated working member downstream of the associated distributor valve as well as to the action of a biasing spring, and an opposite end subjected to a closure pressure coming from the input of the associated distributor valve.

In some operating conditions of hydraulic circuits of the said type situations can arise in which the supply pump sends to one or more of the actuators a considerable output not required by the energy balance of the manoeuvre. This situation can occur, for example, in the case of a linear actuator which controls the raising and lowering of the arm of an excavator, during the movement of a negative load (lowering of the load).

In fact, in this case the negative load acts on the end of the linear actuator cylinder and the movement is controlled by the discharge flow cross-section ("meter-out") of the associated distributor valve and the flow of fluid is normally all discharged. The end of the cylinder housing the linear actuator rod is connected during the movement to the "load-sensing" pump which therefore sends to this side a flow of fluid proportional to the product of the delivery flow cross-section ("meter-in") of the distributor valve and the square root of the "load-sensing" pressure difference, whilst from the end of the actuator cylinder there is discharged a flow rate proportional to the product of the discharge flow cross-section of the distributor valve and the square root of the load pressure.

Since the load on the end of the actuator generates a pressure (of the order of 250 bar) very much greater than that of the "load-sensing" (of the order of 20 bar) and taking account of the ratio (about 1:1.5) of the volumes of the rod end/base end of the actuator cylinder, the flow of fluid sent to the actuator rod end of the cylinder is insufficient and an anti-cavitation valve must be installed on this end of the cylinder.

Since such anti-cavitation valves draw in oil only by the discharge reservoir back pressure, their intervention is not sufficient to provide the required flow rate to the actuator rod end: the pump therefore sends to this end a considerable flow of fluid which is not required by the energy balance of the manoeuvre, with a consequent useless dissipation of power.

The object of the present invention is that of obviating the above-mentioned disadvantage, avoiding unnecessary demands for fluid flow from the pump in the said conditions or in similar operating conditions.

With a view to achieving this object, the subject of the present invention is a hydraulic circuit of the type initially defined, characterised by the fact that at least one of the hydraulic actuators has associated therewith

a fluid flow recovery device including at least one recovery line which interconnects the actuator discharge, upstream of the associated distributor valve with respect to the discharge flow, to the delivery of the actuator between the associated compensator and the associated distributor valve, the said fluid flow recovery line including a unidirectional valve operable to allow the passage of fluid only from the discharge towards the delivery of the actuator to obtain an additional closure pressure on the spool of the compensator.

Thanks to this idea unnecessary demands on the pump capacity in the previously described conditions are cancelled out thanks to the closure of the compensator which isolates the pump from the distributor and the associated actuator.

Moreover, with the arrangements according to the invention the advantage is obtained that, in the case of lowering of a load, the output to the actuator rod end of the actuator cylinder is provided by the flow of fluid leaving the base end which is divided between the discharge cross-section and the delivery cross-section of the distributor. By suitably dimensioning these areas it is possible to avoid the need for an anti-cavitation valve on the rod end of the actuator cylinder.

Naturally, the preceding considerations can be applied to the case in which the operating conditions of the linear actuator are reversed with respect to what has been described above with reference to the lowering of a negative load by the lifting arm of an excavator. For example, in the case of the linear actuator for control of the penetration of the excavating tool of an excavator, the invention permits the unnecessary requirements for output of the "load-sensing" pump towards the base end of the actuator cylinder. In this case,however,it is not in general possible to eliminate the need for an anti-cavitation valve.

Further, the invention can provide a double configuration , when

necessary, by providing the fluid flow recovery device with two recovery lines in parallel for the purpose of obtaining the above-described effect in both directions of operation of the corresponding linear actuator.

Moreover, the recovery device according to the invention is equally applicable, in a double configuration with two recovery lines, to one or more of the rotary hydraulic actuators.

The invention will now be described in detail with reference to the attached drawings, provided purely by way of non-limitative example, in which:

Figure 1 is a hydraulic control circuit diagram according to the invention;

Figure 2 is a simplified diagrammatic view on an enlarged scale of a part of the circuit of Figure 1;

Figure 3 is a first variant of Figure 2;

Figure 4 is a second variant of Figure 2; and

Figure 5 is a simplified diagrammatic view on an enlarged scale of another part of the circuit of Figure 1.

In Figure 1 the essential components of a hydraulic control circuit for the working members of an earth-moving machine are illustrated.

In the illustrated example these working members comprise a series of linear hydraulic actuators 1, 2, 3, 4 serving for the actuation of the excavator arm (raising-penetration-positioning-crowding) and a series of rotary hydraulic motors 5, 6, 7 the first two of which are utilised for the translation manoeuvres of the excavator and the third for the rotation of the excavator arm.

The linear actuators 1-4 are gathered in a group, generally indicated 10, separate and distinct from the group, indicated 11, of rotary motors 5-7.

Supply and discharge of the actuators 1-4 and 5-7 is provided by respective distributor valves 8, 9 associated with the two groups 10,11 respectively. Each distributor valve 8, 9 is positionable in three conditions, corresponding respectively to displacement in a first direction of the associated actuator 1-7, stopping thereof, and displacement in a second direction opposite the first. The input-output connections between the distributors 8, 9 and the associated actuators 1-7 are indicated in the drawing with A_1, B_1 ..... A_7, B_7.

The positioning of the spools of the distributors 8, 9 in the three possible positions is obtained thanks to hydraulic control effected from a servo controlled valve unit, not illustrated in the drawing, including a series of control levers and pedals, known per se, which can be manually positioned in different positions corresponding to the said conditions of the distributors 8, 9. The input-output control connections between the servo controls and the distributors 8, 9 are indicated a_1, b_1 ..... a_7, b_7.

Supply to the distributors 8, 9 (and therefore to the working members 1-7) and to the servo controls, is obtained in the case of the illustrated example by means of two separate hydraulic pumps 12, 13.

The pump 12 is provided with a "load-sensing" control of type known per se, formed by means of a control circuit 14 by means of which the "load-sensing" pressure signals are derived by taking off signals 15 from the distributors 8 and signals 16 from the distributors 9.

Associated with the distributor valves 8, 9 are respective compensators 17, 18 constituted by normally open two-way spool valves inserted in the delivery line 19 of the pump 12 between this latter and the associated distributor valves 8, 9. The compensators 17, 18, which will be returned to below, have, in a manner known per se, the function of maintaining during operation the difference between the pressure delivered by the pump 12 and that in the working members 1-7 substantially constant for

the purpose of ensuring the simultaneity of the various possible working movements of the machine independently of the controlled loads. The hydraulic servo control devices are fed by the pump 13 under the control of a maximum pressure valve 20. Associated with this maximum pressure valve is a valve device, generally indicated 21, the function of which is that of preventing the hydraulic circuit from being able to find itself in saturation conditions. The ways in which the depressurisation valve unit 21 can operate are described and illustrated in European Patent Application No. 85830286.2 by the same applicant.

The rotary hydraulic motors 5, 6 and 7 are associated with braking valve means controlled by the pressure in the delivery duct 19 and prearranged to vary the discharge resistance of the motors in dependence on the pressure existing in the supply duct. These braking valve means are constituted, in a manner known per se from Italian Patent Application No. 67086-A/86 and from corresponding European Patent Application No. 86830260.5, by a single counterbalanced controlled valve 22 inserted in a discharge duct 23 which is common to the three distributors 9 and subjected to the action of a control pressure coming from the pump 13 through a pressure limiting unit, generally indicated 24. This control pressure signal, which corresponds to the lowest supply pressure of the rotary actuators 5-7, could alternatively be derived from a selector valve logic system in a manner known from the above-mentioned Patent documents.

According to the invention, one or more of the actuators 1-7 can be associated with a fluid flow recovery device operatively cooperating with the corresponding compensators 17, 18 to avoid unnecessary demands for delivery from the pump 12 in certain operating conditions.

Embodiments of these fluid-flow recovery devices are illustrated in more detail in Figures 2-5.

Figure 2 relates to the application of the fluid-flow recovery device, generally indicated 25, to the linear hydraulic actuator 1 provided for raising and lowering the excavator arm. Figure 2 shows in simplified and diagrammatic form the delivery circuit from the pump 12 and discharge to a reservoir 26 of the linear actuator 1 in the position of the associated distributor valve 8 corresponding to lowering of a load. In this Figure the distributor valve 8 has been omitted for simplicity and its representation replaced by two schematic representations 8a, 8b of the associated delivery sections ("meter-in" area) and discharge sections ("meter-out" area) respectively through a delivery line 27 and a discharge line 28. As is seen, in the said operating conditions the liquid under pressure coming from the pump 12 is supplied to the cylinder 1a of the linear actuator 1 on the side of the rod 1b, whilst the opposite end 1c of the cylinder 1a is connected to the discharge.

The compensator 17, which is inserted in the duct 19 between the pump 12 and the distributor valve 8, is constituted by a normally open two-position and two-way spool valve 29 having a side 29a subjected to an opening pressure coming from the linear actuator 1 through a line 30 as well as to the action of a biasing spring 31, and an opposite side 29b subjected to a closure pressure coming from the input of the distributor valve 8 through a line 32. Between the compensator 17 and the distributor valve 8 there is disposed a non-return valve 33.

The fluid flow recovery device 25 includes, in the case of Figure 2, a recovery line 34 which interconnects the discharge 28 from the base end 1c of the actuator 1, upstream of the discharge section 8b of the distributor valve 8 with respect to the discharge flow, and the delivery 27 to the rod end 1b of the actuator 1, upstream of the delivery section 8a of the distributor valve with respect to the delivery flow. In the recovery line 34 there are inserted a unidirectional valve 35 operable to allow the passage of fluid only from the discharge 28 towards the delivery 27 of the actuator 1, and a calibrated throttle 36 for control of the fluid flow.

In the operating conditions described above with reference to Figure 2, during a lowering movement of a load, the load on the base end 1c of the actuator 1 generates a pressure (of the order of 250 bar) very much greater than that sent to the rod end 1b so that the pump must normally send to this side a considerable flow of fluid which is not required by the energy balance of the manoeuvre. The presence of the fluid flow recovery device 25 according to the invention in practice cancels out this requirement for fluid flow from the pump 12 in that the pressure acting on the base end 1c of the actuator 1 is transmitted through the recovery line 34 to a point upstream of the delivery section 8a of the distributor valve 8. This pressure then acts through the line 32 on the side 29b of the spool 29 of the compensator 17, with a value significantly greater than that acting on the side 29a and corresponding to the pressure on the rod end 1b of the actuator 1 and the load of the spring 31. Consequently the spool 29 of the compensator 17 is moved to the closure position blocking the requirement for fluid flow from the pump 12.

In the case of Figure 3 the line 32 is connected upstream of the unidirectional valve 33 with respect to the delivery flow. However, this line 32 could alternatively be connected downstream of the valve 33, as is illustrated in the variant of Figure 3 in which the same reference numerals as in Figure 2 have been utilised.

The variant of Figure 4 shows the application of the flow rate recovery device 25 according to the invention to the case in which the linear actuator 1 is in discharge through the discharge section 8b of the distributor valve 8 from the rod end 1b and in delivery from the base end 1c through the delivery section 8a of the distributor valve 8. The circuit configuration and the manner of operation are entirely identical to those previously described with reference to Figure 3.

The recovery device 25 can have a double configuration, as illustrated in Figure 1 with reference to the linear actuator 2, by utilising two recovery

lines 34 in parallel, with respective non-return valves 34 and throttles 36 connected one to the line 27 and the other to the line 28 of the actuator.

Figure 5, in which the same reference numerals are used as in the preceding Figures (and in which 9a, 9b indicate respectively the delivery sections and discharge sections of the distributor valve 9), illustrate the application to a rotary motor 5 with a single recover line 34, whilst Figure 1 shows the application of the double configuration to the rotary motor 6 with two recovery lines 34 joined together in parallel.

The modes of operation of the recovery device 25 applied to such hydraulic motors are entirely similar to those described previously with reference to linear actuators.

CLAIMS

1. A hydraulic control circuit for working members of earth-moving machines including a pump for supplying a hydraulic fluid under pressure and a plurality of reversible hydraulic actuators, in part linear and in part rotary, for the actuation of associated working members, each of which has associated therewith a respective hydraulic spool valve connected to the delivery and discharge of associated working members and positionable with continuous adjustment by associated control means into three positions corresponding to the displacement of the working member in a first direction, stopping thereof, and displacement in a second direction opposite to the first, and pressure compensators of the "load-sensing" type interposed between the said supply source and the said distributor valves for maintaining substantially constant the difference between the delivery pressure from the said supply source and the pressure of the working members, the said compensators including normally open two-way spool valves each having a side subjected to an opening pressure coming from the associated working member downstream of the associated distributor valve as well as the action of a biasing spring, and an opposite side subjected to a closure pressure coming from the inlet of the associated distributor valve, characterised in that at least one of the hydraulic actuators (1-7) has associated therewith a fluid-flow recovery device (25) including at least one recovery line (34) which interconnects the discharge (28) of the actuator (1-7) upstream of the associated distributor valve (8,9) with respect to the discharge flow, and the delivery (27) of the actuator (1-7) between the associated compensator (17,18) and the associated distributor valve (8,9), the said fluid-flow recovery line (34) including a unidirectional valve (35) operable to allow the passage of fluid only from the discharge (28) towards the delivery (27) of the actuator (1-7) to obtain an additional closure pressure on the spool (29) of the compensator (17, 18)

2. A circuit according to Claim 1, characterised in that the recovery line (34) further includes a calibrated throttle (36).

3. A circuit according to Claim 1 or Claim 2, characterised in that the or each fluid-flow recovery device includes two recovery lines (34) connected in parallel.

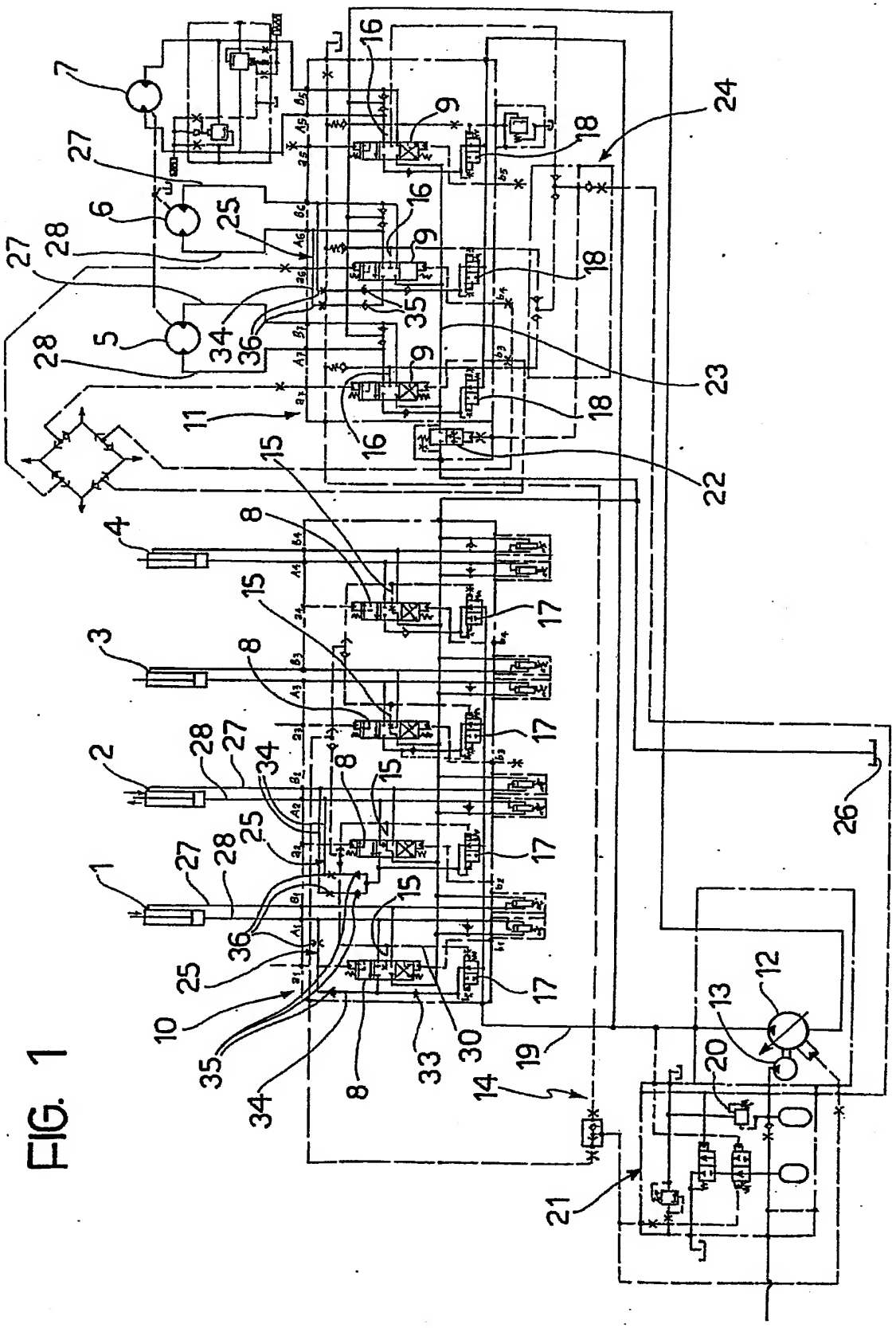

FIG. 1

FIG. 3

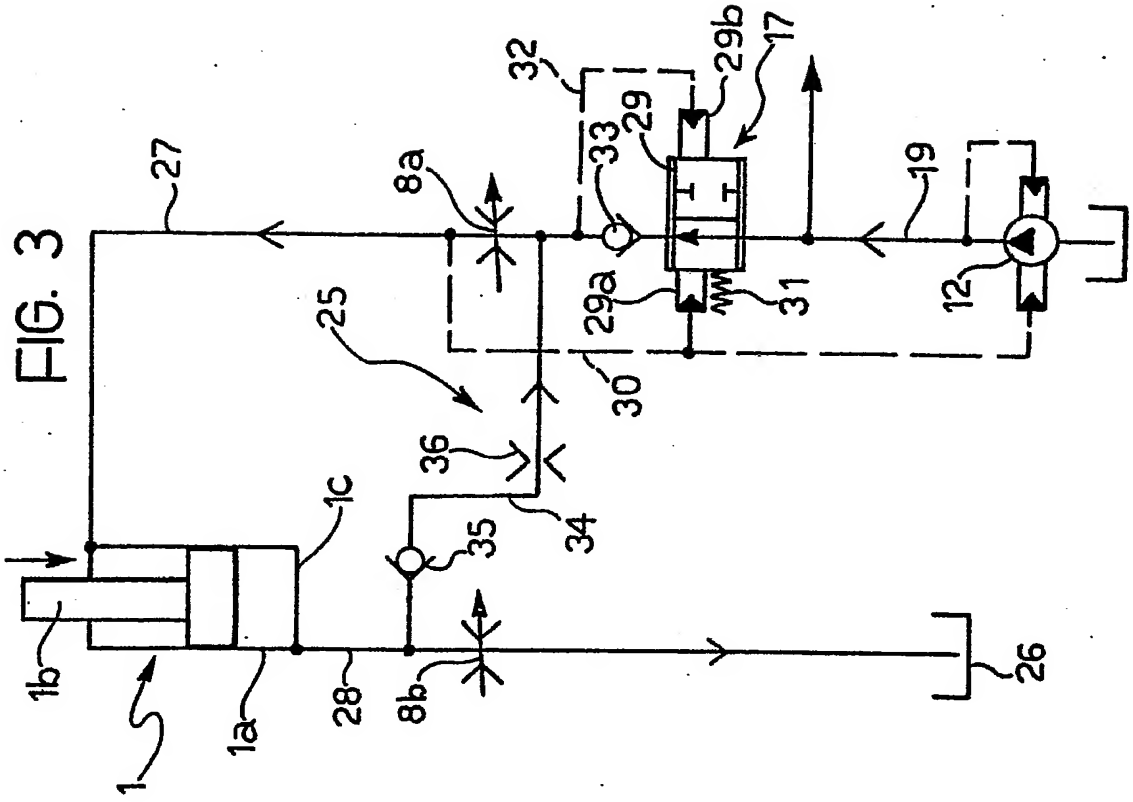
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FIG. 2

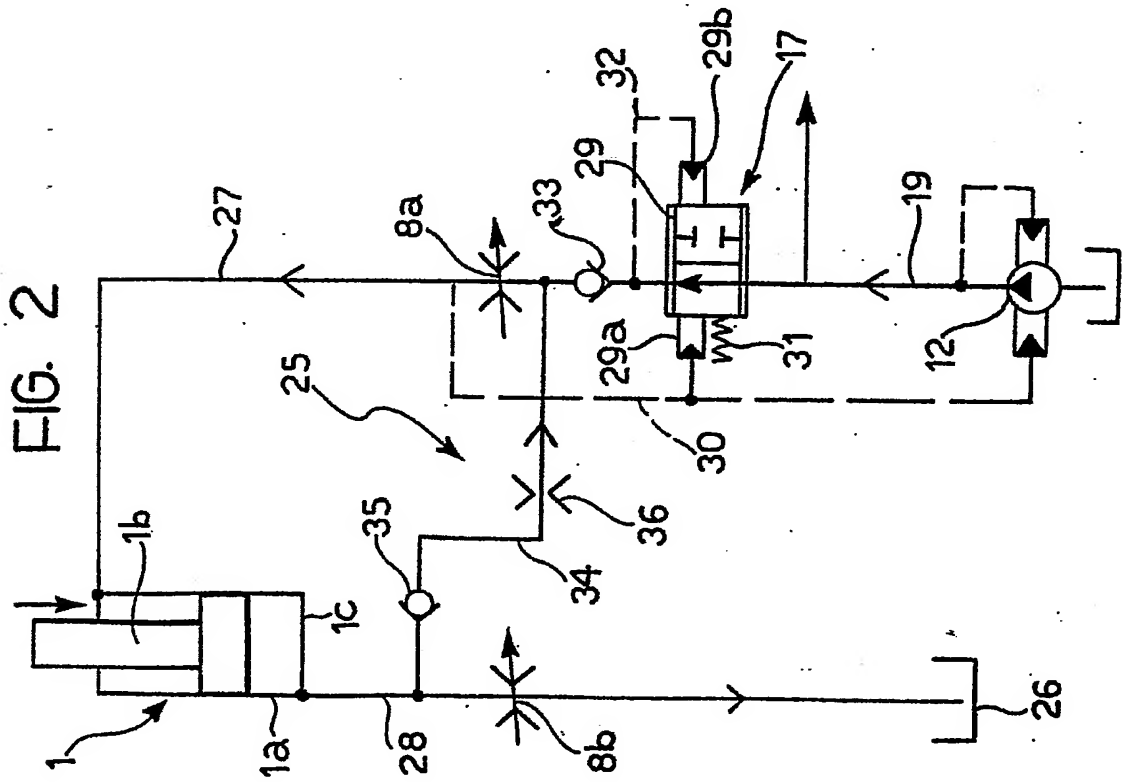
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FIG. 5

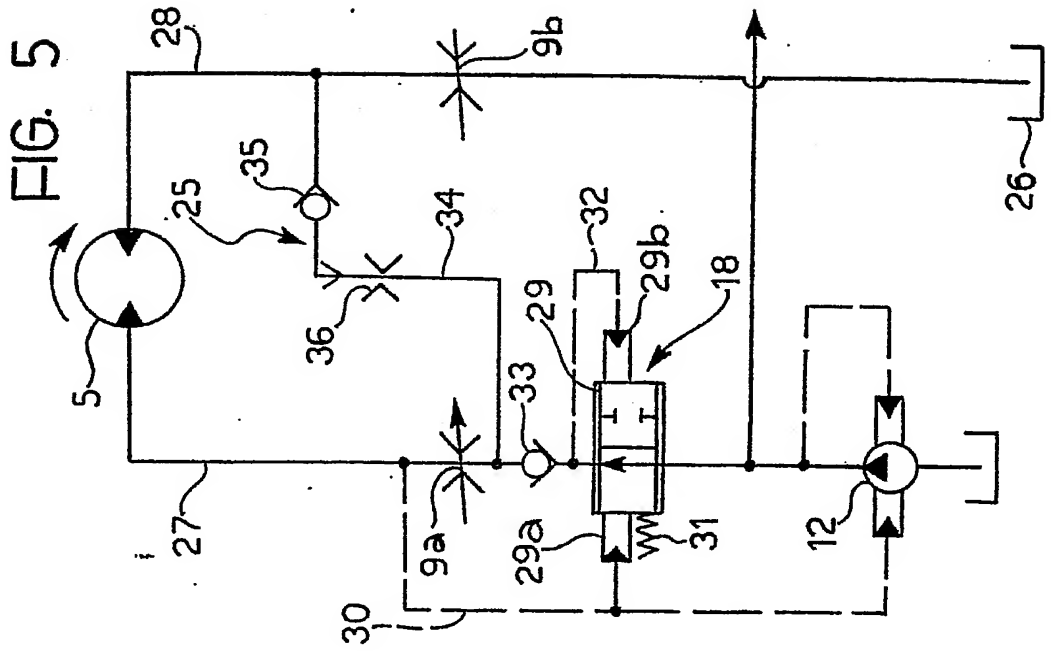
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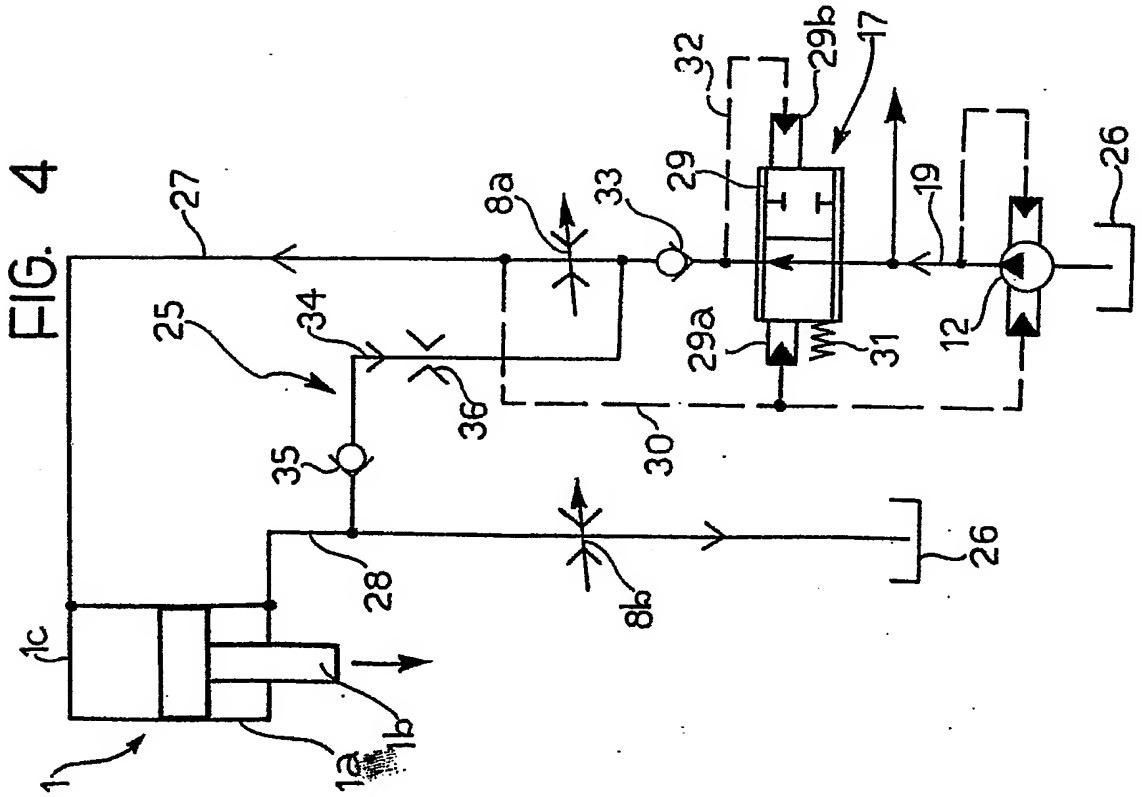
FIG. 4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EUROPEAN SEARCH REPORT

Application number

EP 87 83 0015

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	FR-A-2 537 184 (U. REINECKE et al.) * Page 3, line 20 - page 5, line 30; figures 1-5 *	1	E 02 F 9/22 E 02 F 3/43 F 15 B 11/08 F 15 B 13/02
A	US-A-3 467 126 (D.R. BALLARD et al.) * Claims 1-4; figures 1-4 *	1,3	
A	US-A-4 216 702 (C.L. BRUNDIDGE et al.) * Abstract; figure 5 *	1	
A	PATENT ABSTRACTS OF JAPAN, vol. 7, no. 261 (M-257)[1406], 19th November 1983; & JP-A-58 142 003 (MITSUBISHI JUKOGYO K.K.) 23-08-1983	1,3	
A	FR-A-1 401 412 (ETS. FAUCHEUX) * Page 3, lines 6-20; figure 2 *	1,2	TECHNICAL FIELDS SEARCHED (Int. Cl.4) E 02 F F 15 B
A	US-A-4 383 412 (G.T. PRESLEY) * Abstract; figures 1-4 *	1	
A	US-A-4 364 304 (H.S. ANDERSEN) * Claim; figure 4 *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	02-07-1987	ANGIUS P.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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